Studying distant dwarf galaxies with GEMS and SDSS

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Abstract. We study the colors, structural properties, and star formation histories of a sample of ~ 1600 dwarfs over look-back times of ~ 3 Gyr ($z = 0.002 - 0.25$). The sample consists of 401 distant dwarfs drawn from the Galaxy Evolution from Morphologies and SEDs (GEMS) survey, which provides high resolution *Hubble Space Telescope (HST)* Advanced Camera for Surveys (ACS) images and accurate redshifts, and of 1291 dwarfs at 10–90 Mpc compiled from the Sloan Digitized Sky Survey (SDSS). We find that the GEMS dwarfs are bluer than the SDSS dwarfs, which is consistent with star formation histories involving starbursts and periods of continuous star formation. The full range of colors cannot be reproduced by single starbursts or constant star formation alone. We derive the star formation rates of the GEMS dwarfs and estimate the mechanical luminosities needed for a complete removal of their gas. We find that a large fraction of luminous dwarfs are likely to retain their gas, whereas fainter dwarfs are susceptible to a significant gas loss, *if* they would experience a starburst.

1. Introduction

The evolution of dwarfs is a complex problem, where evolutionary paths may depend on a variety of external and internal factors. Our knowledge of the local volume (< 8 Mpc) has deepened, in particular due to strong efforts in determining distances to many nearby galaxies (Karachentsev et al. 2003, and references therein). However, it is still unclear what governs the evolution of dwarfs in low density regions and how the different morphological types form.

Here, we present a study of the properties of dwarf galaxies over the last 3 Gyr ($z = 0.002 - 0.25$)[1] drawn from GEMS (Rix et al. 2004) and SDSS (Abazajian et al. 2004).

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[1] We assume a flat cosmology with $\Omega_M = 1 - \Omega_\Lambda = 0.3$ and $H_0 = 70$ km s^{-1} Mpc^{-1}.
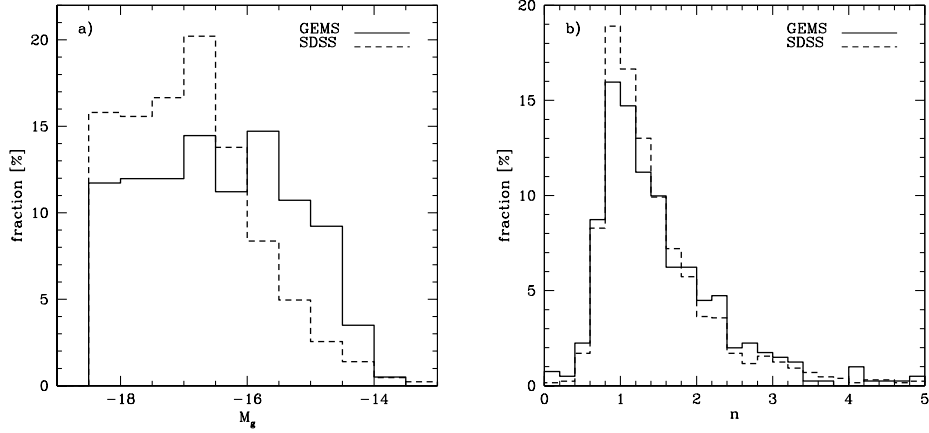
Figure 1.   **a)** The g-band luminosity distribution of the GEMS and SDSS samples. The median value for the GEMS dwarf sample is -16.51 mag and for SDSS -16.95 mag. **b)** Histograms of the Sersic index n. The median values are 1.32 and 1.25 for GEMS and SDSS, respectively.

2.   Basic properties of the sample

Our starting sample consists of 988 dwarfs from the GEMS survey in the redshift range $z \sim 0.09 - 0.25$ (corresponding to look-back times of 1 to 3 Gyr), and a comparison local sample of 2847 dwarfs with $z < 0.02$ from the NYU Value-Added low-redshift Galaxy Catalog (NYU-VAGC, Blanton et al. 2005) of the SDSS, which have been identified and extracted by applying an absolute magnitude cut of $M_g > -18.5$ mag. The surface brightness profiles of the dwarfs in this sample have subsequently been fitted with a Sersic model using GALFIT (Peng et al. 2002). Finally, we limited the sample to objects with an effective surface brightness brighter than 22 mag arcsec^{-2} in the z band, which corresponds to the completeness limit of the SDSS sample (Blanton et al. 2005). The final sample consists of 401 dwarfs from GEMS and 1291 dwarfs from SDSS. Figure 1 shows the distributions of the luminosities and Sersic indices.

3.   Global colors and star formation histories

The comparison of the global colors of the two samples shows that the GEMS dwarfs are significantly bluer than the SDSS dwarfs, which is apparent in the histograms shown in Figure 2a. A KS-test yields a probability of $\sim 2 \times 10^{-41}$ that the two color distributions stem from the same parent distribution. In order to examine the origin of this color difference, we compare the colors of our sample dwarfs to star formation (SF) models from *Starburst 99* (Leitherer et al. 1999) in Figure 2b. The general color difference between the two samples is consistent with the color evolution of models combining a starburst (SB) with continuous SF on a low level. The model tracks show rather long periods of time with roughly constant $U - B$ colors, while the $B - V$ colors are becoming significantly redder. This reddening occurs over time spans comparable to the
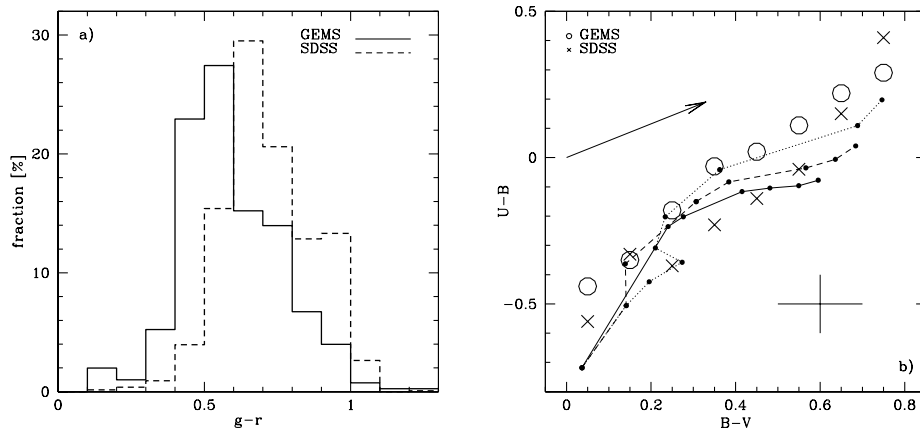
Figure 2.   **a)** The $g - r$ color distributions for both samples. The median colors are 0.57 and 0.70 for GEMS and SDSS, respectively. **b)** Color-color plot for the two samples. The distribution of the galaxies is represented by the mean $U - B$ colors in 0.1 mag $B - V$ color bins. The lines represent models, where a continuous SF with a constant rate of $SFR = 0.03$ M$_\odot$ yr^{-1} and a metallicity of $Z = 0.004$ has been combined with various single SBs starting at different times. For all models a Kroupa IMF has been used. Models start at 0.1 Gyr (left) and end at 15 Gyr (right) *Solid line:* A single SB with a mass of 3×10^8 M$_\odot$ and $Z = 0.0004$ starts at 0.1 Gyr. *Dashed line:* A single SB with a mass of 3×10^8 M$_\odot$ and $Z = 0.004$ starts at 0.9 Gyr. *Dotted line:* A single SB with a mass of 5×10^8 M$_\odot$ and $Z = 0.02$ starts at 3.9 Gyr. The error bars represent the errors of the single color measurements. The arrow indicates the effect of dust on the colors (Schlegel et al. 1998).

average look-back time of the GEMS sample and the amount of reddening is in good agreement with the color difference between the two samples.

4.   Star formation rates and feedback

Using the rest-frame luminosity in a synthetic UV band centered on the 2800Å line, we estimate the star formation rate (SFR) of the dwarfs in the GEMS sample, assuming continuous SF over the last 10^8 years, which is likely the case for a majority of our dwarfs. In Figure 3a we plot the *normalized* SFR versus M_B. In a next step, we estimate the mechanical luminosities (MLs) needed for the complete removal of the gas from the dwarfs. The estimate is based on the blow-away model by Mac Low & Ferrara (1999). In this model, the MLs depend only on the mass, which we derive from the V-band luminosities, and the ellipticity. In Figure 3b we compare these MLs with the ones expected for the measured SFRs. We find that for their derived SF histories, the luminous ($M_B = -18$ to -16 mag) dwarfs are likely to retain their gas and avoid blowaway. However, there are a fair number of low luminosity dwarfs ($M_B = -14$ to -16) that are susceptible to a complete blowaway of gas, *if they were* to experience a SB. However, in practice, only a small fraction of these low luminosity dwarfs *may be actually undergoing* a SB. Even though, we do not have any clear evidence
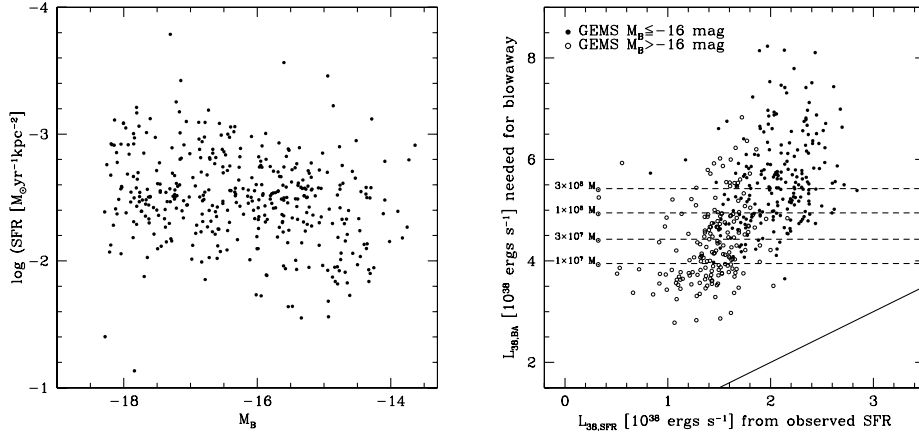
Figure 3.   **a)** The normalized SFR versus M_B. The SFRs have been estimated from the 2800Å continuum fluxes (L_{2800}) and using the equation $SFR[\mathrm{M_\odot yr^{-1}}] = 3.66 \times 10^{-40} L_{2800} \,[\mathrm{ergs\ s^{-1}\ \lambda^{-1}}]$ adopted from Kennicutt (1998). These SFRs have then been divided by the isophotal area provided by Sextractor. **b)** Plot of the ML needed for a complete blowaway of the gas in dwarfs versus the MLs inferred from the SFRs. The four dashed lines mark the peak MLs reached of SBs with the indicated masses. The solid line corresponds to $L_{38,SFR} = L_{38,BA}$.

that some dwarfs in our sample experience a SB at the time of observation, we are also not able to rule this out. The derived MLs stem from the SFRs, which have been determined assuming that the dwarfs had a constant SFR over the last 10^8 years. In addition, we used the near-UV luminosities, which could be affected by dust. In view of these uncertainties, the derived SFRs have to be considered as lower limits.

References

Abazajian, K., et al. 2004, AJ, 128, 502
Blanton, M. R., et al. 2005, AJ, 129, 2562
Karachentsev, I. D., et al. 2003, A&A, 398, 479
Kennicutt, R. C. 1998, ARA&A, 36, 189
Leitherer, C., et al. 1999, ApJS, 123, 3
Mac Low, M.-M., & Ferrara, A. 1999, ApJ, 513, 142
Peng, C. Y., Ho, L. C., Impey, C. D., & Rix, H. 2002, AJ, 124, 266
Rix, H., et al. 2004, ApJS, 152, 163
Schlegel, D. J., Finkbeiner, D. P., & Davis, M. 1998, ApJ, 500, 525